RESEARCH ARTICLE

Revised criteria system for a national assessment of threatened habitats in Germany

Stefanie Heinze[1], Peter Finck[1], Ulrike Raths[1], Uwe Riecken[1], Axel Ssymank[1]

1 *German Federal Agency for Nature Conservation, Deptartment of Biotope Protection and Landscape Ecology, Konstantinstrasse 110, D-53179 Bonn, Germany*

Corresponding author: Stefanie Heinze (stefanie.heinze@bfn.de)

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Abstract

The Red List of threatened habitat types in Germany was first published in 1994 and it is updated approximately every ten years. In 2017 the third version was published by the German Federal Agency for Nature Conservation. In the course of the revision, the criteria system was also extended. In doing so, an attempt was made to find a compromise between the consideration of international developments that had taken place and existing national requirements. In particular, short-term developments should become visible through the German Red List status. In addition to 'National long-term Threat', the valuation now also includes 'Current Trend' and 'Rarity'. Following the IUCN's approach, the collapse risk is now represented on the basis of several criteria. However, in contrast to the IUCN procedure, where the worst evaluated criterion is determinative for Red List status, in our procedure all criteria are included in the evaluation. To counteract misleading signal-effects for management decisions, all significant criteria have an influence on the resulting German Red List status (RLG). They are combined in an assessment scheme. In order to map the overall risk of loss, both the long-term threat as a historical reference value and furthermore the current trend must have an influence on RLG. As a result, 65% of habitat types have differing risk of loss.

Keywords

collapse risk, criteria, ecosystem, endangered habitats, nature conservation, risk of loss

Introduction

The protection of biotopes, which aims to preserve a habitat and its complete biocenosis, has become a core instrument of nature conservation in Europe since the 1970s (e.g. Erz 1971; Blab 1984; Kaule 1986; Blab et al. 1993, 1995; Riecken et al. 1994; Essl et al. 2002). Global standards of Red List categories and criteria for ecosystems have recently been proposed by the International Union for Conservation of Nature (IUCN) (Bland et al. 2017). In Europe, Red Lists of biotopes/habitats (on the varied use of the terms 'biotope', 'habitat' and 'ecosystem' see chapter 'Terms and basic concepts') have a noteworthy tradition in several countries (for a comprehensive overview see Rodwell et al. 2013; Savio and Gaudillat 2015; Finck et al. 2017; IUCN 2019). Several European countries have developed distinct national specific assessment systems (e.g. Riecken et al. 1994, 2006; Essl et al. 2002; Dimopoulos et al. 2005; Doniţă et al. 2005; Petrella et al. 2005; Raunio et al. 2008; Härtel et al. 2009; Essl and Egger 2010; Biserkov et al. 2015; Finck et al. 2017).

Consequently, recently developed national approaches had to find a balance between national specific requirements and international comparability (e.g. Delarze et al. 2015, 2016; Finck et al. 2017; Kontula and Raunio 2019). Therefore, instead of exclusively assessing the long-term threat to habitats, the most recently published Red Lists assess different symptoms of the overall 'ecosystem collapse risk' (cf. Bland et al. 2017, 2018). The evaluation of the 'collapse risk' requires the assessment of the condition of an ecosystem type over different time periods – from historical to future trend. Furthermore, the analysis has to consider both reduction in area and in ecosystem quality. The European Commission has funded a comprehensive project to develop a 'European Red List of Habitats' (Gubbay et al. 2016; Janssen et al. 2016) which is based on the IUCN approach. However, Gubbay et al. (2016) and Janssen et al. (2016) also had to allow for European-specific modifications in the application of the IUCN criteria. Therefore, for example, the criteria which assess functional symptoms (degradation of ecological processes: Criteria C/D) have been combined in this project because it has been impossible to separate biotic and abiotic degradation processes.

In 2017, a third updated edition of the 'German Red List of threatened habitats' was published (Finck et al. 2017). The evaluation system was revised in the course of the new edition. The following main considerations were taken into account: (1) the new criteria and categories should clearly relate to those used in previous editions and thereby allow for comparisons to earlier editions (Riecken et al. 1994, 2006); (2) as far as they are also relevant for habitats, existing updated national standards for Red List assessments of species (Ludwig et al. 2009) should be considered (e.g. assessment scheme, consideration of different time frames, and specific risk factors like rarity); (3) and, as many aspects as possible should be taken into consideration from both the IUCN concept (Keith et al. 2013; Bland et al. 2017) and the approaches currently used for the European Red List of Habitats (Gubbay et al. 2016; Janssen et al. 2016).

Red Lists of habitats are characterised by their direct spatial reference and are therefore explicitly focused on landscape planning and actors in the field of habitat

management and practical nature conservation. In Germany, the Red List also serves as a technical basis for legal biotope protection. Therefore, the Red List status by itself should indicate current needs for action and also success in nature conservation, thus functioning as a basis for political decisions which concern the prioritisation of nature conservation measures (Gigante et al. 2018; Alaniz et al. 2019). Taking into account the above cited considerations, the criteria system of the German Red List has been considerably revised to indicate the threat to habitat types in Germany under current national threat conditions. Accordingly, an evaluation scheme was developed in which the short-term trend also has a clear influence on the resulting Red List status.

The objective of this paper is to present the recently revised assessment procedure for habitat types in Germany and to contribute to further discussion of an appropriate method for Red List assessment for habitats (see also Janssen et al. 2016).

Terms and basic concepts

Blab et al. (1995) defined a 'biotope type' as an idealised type, derived from similar biotopes in the field, having specific ecological, unique, and more or less constant environmental conditions for animal and plant life. For practical use, the definition is restricted to a certain minimum size, which can still be mapped in the field. The IUCN uses the term 'ecosystem' as a classification unit. The definition of the country-specific terms 'habitat' or 'biotope' used in Europe includes both biotic and abiotic elements, as well as ecological and spatio-functional interactions (see Riecken et al. 1994, 2006) and is therefore comparable to the definition of an 'ecosystem' (e.g. Bland et al. 2017). Following the common usage in other European countries, we will hereafter use the term 'habitat' instead of 'biotope', which is actually the common expression in Germany and functions as an applied mapping unit (cf. Rodwell et al. 2013).

The Red List assessment is based on a complete standard list of habitat types occurring in Germany (Riecken et al. 2003). This list covers the entire range of the German landscape – pristine (cf. BfN 2010), technical (e.g. buildings and transport infrastructure) and cultural habitat types. All these types partly represent the biodiversity of the cultural European landscape (cf. Agnoletti and Rotherham 2015). Only minor modifications of the standard list have been introduced for inland habitats in the third edition to consider advanced knowledge. However, for the marine standard habitat list a complete revision was necessary following new international standards (HELCOM 2013; Finck et al. 2017).

The German Red List of habitats is revised in an approximately ten-year-evaluation cycle. Experience has shown that sufficient monitoring data are available from the federal states within this period. In addition, improvements and deteriorations in the state of conservation can be observed within this period as a result of current risk factors. As proposed by the IUCN (Keith et al. 2015), our assessment system evaluates the overall 'risk of loss' of ecosystems, which manifests itself in the collapse of ecosystems.

In the third edition of the German Red List, we derive the 'German Red List status' (RLG) by combining three different criteria. Since the publication of the first edition of the Red List in 1994, the criteria system for assessing the overall risk has been continuously enhanced. This development is justified in many ways, including by improved knowledge, a better data basis, and new international standards. In earlier editions, only the long-term trend with information on changes in area and quality was included in the overall assessment (Riecken et al. 1994, 2006). The current trend was introduced in 2006 as additional information; the rarity was first assigned as a Red list category (cf. Riecken et al. 2006). In the latest edition, the 'Current Trend' (T) and the 'Rarity' (R) were introduced as further criteria which can positively or negatively influence the degree of endangerment of a habitat based on the 'National Long-term Threat'(nTH). By taking into account these two new criteria (which represent habitat conditions within time windows of the recent past, present and near future), current successes and negative developments are now directly represented by RLG (Fig. 1).

Categories are specified by verbal-descriptive definitions since evaluations for several habitats are still based on expert judgement. There was a broad national consensus that it is not possible to exclusively derive individual threat categories from quantitative values as proposed by Rodríguez et al. (2011, 2015). However, even for well-known habitat types the available knowledge is far from sufficient to compile all the required quantitative data. It remains to be seen whether these deficiencies in data
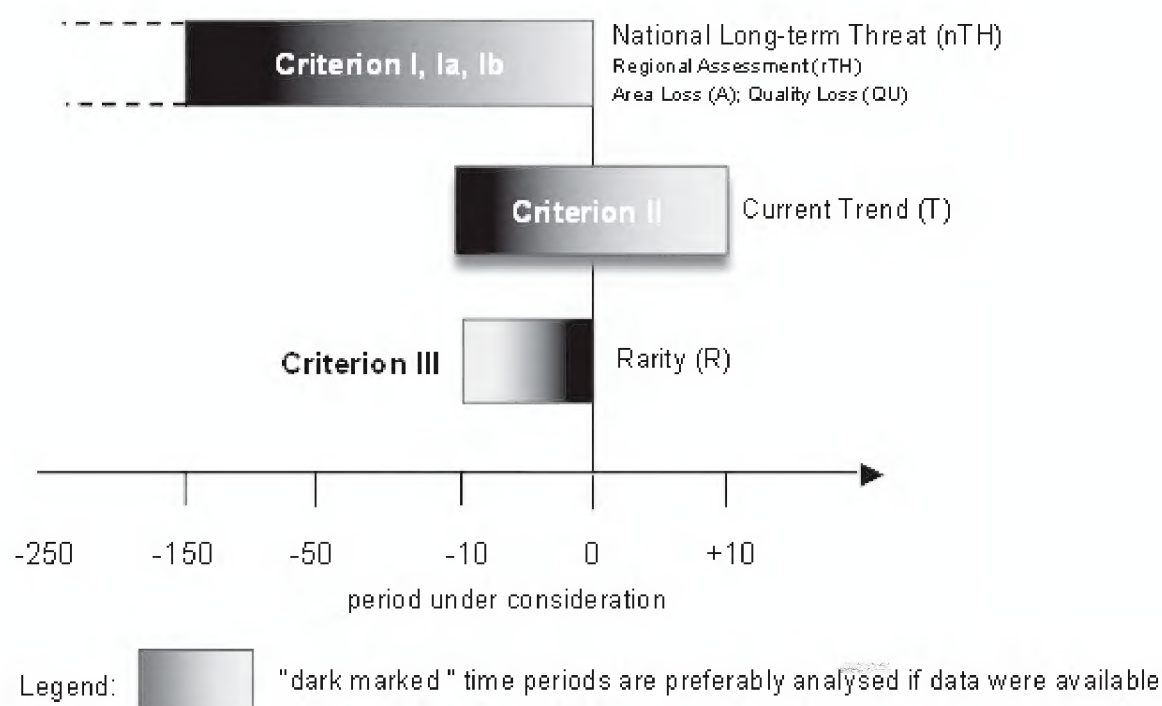

Figure 1. Time frames of the three red listing criteria of the German Red List (Finck et al. 2017). For the long-term evaluation (nTH), mainly anthropogenic spatial (sub criterion AL) and qualitative (sub criterion QUL) changes over the last 50–150 years (sliding time frame) are assessed for the major regional landscape units. The estimation of the 'Current Trend' (T) is based on development over the last ten years and a forecast for the near future (maximum ten years). A higher risk of loss is basically assumed for habitat types which are 'Extremely Rare' at present (R). The latter includes both 'natural' rarity as well as rarity as a result of human impact.

can be resolved in the future, and whether quantitative data can then also be used as a basis in the national Red List of threatened habitats. Verbal descriptive categories can be particularly useful for countries for which complete quantitative information on the occurrence of habitats is not available.

Methods of Red List-assessment for threatened habitats in Germany

Evaluation procedure

To counteract misleading signal-effects for management decisions, we established a mechanism in the assessment procedure to ensure that all significant criteria have an influence on the resulting RLG. Thus, RLG is determined by a step-by-step evaluation procedure (Fig. 2).

Regional assessment: Regional Long-term Threat

For the long-term risk assessment mainly anthropogenic spatial (sub criterion AL) and qualitative (sub criterion QUL) changes over the last 50–150 years (sliding time frame) are assessed for the major landscape regions (see Fig. 3). For this purpose, the

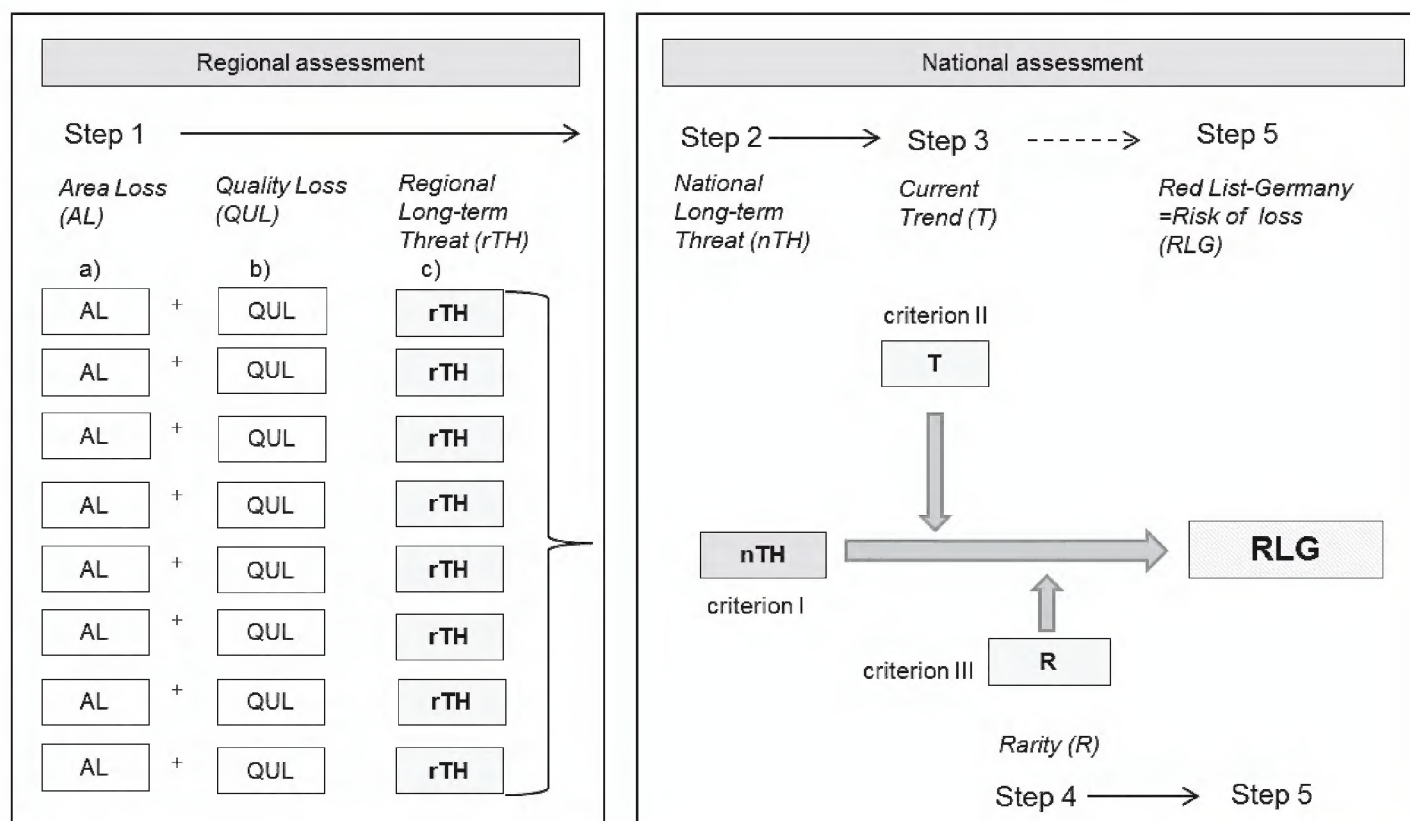**Figure 2.** Stepwise Red List assessment for habitat types in Germany. The 'National Long-term Threat' (nTH) is derived from the 'Regional Long-term Threats' (rTH) of eight major landscape regions (Step 1, 2) (see Fig. 3). After that, the degree of endangerment is upgraded or devalued consecutively, first by applying criterion T (Step 3) and then criterion R (Step 4). RLG represents the overall 'Risk of loss' (Step 5) (cf. BfN 2017).

time period between 1850 and 1950 is set as the reference. In most cases, an earlier reference stage cannot be used due to insufficient data. Hence, the considered reference period does not represent the pristine stage of nature as still existed in the Middle Ages in greater parts of Europe. Specific to the habitat, the initial phase of industrialisation (~1850) or rather the situation before the massive intensification in agriculture after the Second World War started (~1950) was chosen.

A similar reference period for the assessment of the long-term threat in Germany is used by Ludwig et al. (2009) for species, and also in Red Lists of habitats from several German federal states which were used as data sources (e.g. Buder and Uhlemann 2010; Von Hengel and Westhus 2011; Zimmermann et al. 2011; Von Drachenfels 2012). The IUCN uses an earlier reference period for the long-term trend; here the relative changes since 1750 are considered (Bland et al. 2017).

For each of the defined eight major landscape regions (see Fig. 3) a risk assessment is performed with regard to the two sub-criteria AL and QUL. Subsequently, consolidation of these sub-criteria into the 'Regional Long-term Threat' (rTH) is carried out (see Fig. 2, step 1). Following the 'precautionary principle', the highest risk category obtained by any of the two sub-criteria is used as the overall rTH. The verbal-descriptive definitions for the categories of the sub criteria AL and QUL, and the overall categories for rTH, are presented in Table 1 as they also correspond to criterion I (nTH), which only differs in spatial scale of assessment.

The sub-criterion AL represents the estimated long-term loss in area of occupancy and the decline in number of sites of habitats (by demolition, building activities, changes in land use, etc.). AL has been described in detail by Blab et al. (1995) (here criterion I). Hereby, the historical ideal condition that belongs to a habitat concerning total area and site density is used as a hypothetical reference to assess threats. In fact, this ideal situation currently rarely exists for any habitat type and can only be described in approximation. In some well-documented cases (e.g. bogs, heathland, ponds, hedges, and unmodified running waters) precise data for the net loss of area are available over a longer period. However, in most cases additional expert judgement is needed to assess this sub-criterion.

Apart from direct loss of total area and decrease in number of sites, habitats can be threatened in particular by qualitative changes and deterioration represented by sub-criterion QUL. Typically, this has adverse effects on the abiotic conditions as well as on the structural appearance, the typical set of characteristic species, and on ecological interactions (see Blab et al. 1995). As the discrepancy from a habitat's ideal or (semi)-natural state increases, it becomes more endangered. An 'ideal state' in quality for each habitat type must be elaborated to serve as a reference with regard to all relevant parameters (essential for the value and possible colonisation of the habitat type by typical species). This reference has to consider, among other parameters, the historic conditions, known abiotic requirements, and ecological requirements of typical animal or plant species or plant communities. However, this is linked to methodical problems. In a number of cases the 'ideal' or 'historic' state is not sufficiently known or can only be described in general terms. Therefore, expert judgement is additionally needed to assess QUL. Given that it is often difficult or impossible to separate biotic and abiotic deg-

Boundaries of physiographic units

Boundaries of major landscape regions

Figure 3. Map of the regions delimited for the regional threat classification of habitats (major landscape regions; red outlines). For ecological characterisation, Germany can be subdivided into natural units. The figure is based on the system of Meynen and Schmithüsen et al. (1953–1962). For the application in the habitats directive (Natura 2000) and the risk assessment of habitats Ssymank, A (1994) has restructured and generalised the system. The classification of major landscape units is based on physiographic units (black outlines; for a reference list see Annex V.6, Finck et al. [2017]) according to Ssymank et al. (1998) and Petersen et al. (2003).

Table 1. Verbal descriptive definition of criterion I 'National Long-term Threat' (nTH). Following the 'precautionary principle', the highest risk category obtained by any of the two sub-criteria AL and QUL is defined as the overall value of rTH and subsequently nTH.

Criterion I: National long-term threat (nTH)		Sub-criterion Ia: Area loss (AL)	Sub-criterion Ib: Quality loss (QUL)
Scale of assessment:			
Step 1: regional scale (rTH); Step 2: upscaling to national scale (nTH)		Regional	Regional
Category	Description	Definition: verbal-descriptive	Definition: verbal-descriptive
0	Collapsed	Types of habitats which were previously present in the area considered but today can no longer be proven to exist.	Types of habitats with their quality affected so severely that typical or natural variants are completely destroyed.
1	Critically Endangered	Types of habitats of which only a small part of the original area still exists. With the causes of threat continuing and without any activities for protection and management, complete destruction has to be expected in the near future.	Types of habitats with their quality being negatively affected in nearly their whole range, so that typical or natural variants are only left in one or very few sub regions and threatened by complete destruction in a short time.
2	Endangered	Types of habitats with a heavy decline in area in nearly the whole region considered or already extinct in several (sub) regions.	Types of habitats with their quality being negatively affected in a way that – a decline of typical variants can be stated in nearly the whole area of interest or – typical variants already became extinct in several (sub)regions.
3	Vulnerable	Types of habitats with negative development of area over a broad range of the considered region, or locally extinct at numerous sites.	Types of habitats with their quality being negatively affected in a way that – a decline of typical variants in several sub regions can be stated or – typical variants already became locally extinct at numerous sites.
V	Near Threatened	Types of habitats with negative development (also in the long term), thus being potentially threatened by loss of area if not already threatened according to categories 1–3.	Not defined in the German assessment
*	Least Concern	Presumably not endangered at present	
?	Data Deficient	Classification not possible because of insufficient data	
#	Evaluation not reasonable	These are types of habitats that – although they may show declining tendencies – are considered 'undesirable' from a nature conservation point of view. Examples would be forests of non-native tree species, arable fields on peat soil, or certain degeneration stages of fens and bogs.	
–	Not Evaluated	No corresponding category in the national assessment; all types have been evaluated based on a complete reference list for Germany	

radation processes as proposed by Rodríguez et al. (2011), theses aspects are combined to QUL in the German Red List. This corresponds to a similar approach e.g. in the European Red List of Habitats (Janssen et al. 2016) and in the Red List of Ecosystems of Switzerland (Delarze et al. 2016).

Criterion I: National Long-term Threat

The assessment of nTH in the current edition corresponds to the overall Red List category of the second edition because in 2006 only nTH was considered to deter-

mine RLG (Riecken et al. 2006). The assessment is based on an upscaling from rTH to nTH, i.e. from the regional to the national scale (Fig. 2, step 2). Median values of all rTH values for every habitat type are calculated (of a maximum of seven terrestrial regions, i.e. all regions where the habitat type is present).

If regions differ extremely in rTH, the most representative region(s) for each habitat turned the balance. The reference period corresponds to that of rTH. For nTH the categories and definitions remain largely unchanged compared to earlier editions of the Red List Germany (Table 1). However, in contrast to previous editions, intermediate values (1–2, 2–3) are no longer used in this context. The evaluation of nTH is the starting value underlying the Red List assessment scheme (Table 3), whereas the following criteria T and R 'only' cause an upward or downward revaluation of the category.

Criterion II: Current Trend

The 'Current Trend' (T) in total area (and number of sites) is assigned at the national level. The estimation of T is based on development over the last ten years and a forecast for the near future (maximum ten years). This period corresponds to the updating cycle of the Red List Germany. A comparable criterion is used in Germany for the Red List assessment of species, but without the future assessment (short-term population trend, cf. Ludwig et al. 2009). The reporting format for the main results of the monitoring referred to in Article 11 of the European Union (EU) Habitats Directive for habitat types in Annex I also considers short-term trends over a similar time horizon (sliding window over 12 years, cf. DG Environment 2017.). A criterion with a similar idea was also integrated into the Finnish assessment (Kontula and Raunio 2009). They estimate the 'projected quantitative and qualitative change in the near future (criterion A2/B2)' in a time frame of 20–30 years. Bland et al. (2017) use a 50-year period for short-time assessments. T is included in the overall assessment of RLG in this new edition for the first time. Considering the availability of data sources, five categories are used (Table 2). For all endangered and near threatened types of habitats, which show a negative short-term trend, the threat category increases by half a value based on the assessment of nTH. For endangered/near threatened types of habitats which have a stable trend the threat category decreases (i.e. improves) by half a value because we interpret stabilisation as success of nature conservation activities. For endangered habitat types with a currently positive short-term trend, the threat category improves by one value (Fig. 2, step 3).

Criterion III: Rarity

In the revised assessment scheme, a higher risk of loss is basically assumed for habitat types which are extremely rare. They are characterised through very few or very small occurrences and are therefore usually very sensitive to the loss of individual sites since

Table 2. Definition of criterion II 'Current Trend' (T) and implication for the risk assessment procedure.

Symbol	Category	Definition	Change in threat category (based on nTH)
↓	Negative	In the last ten years, a decrease in the total stock of the total area, or at least in large parts of the area, can be observed and is likely to continue in the coming years.	− 0.5
→	Stable	The total area has been largely constant over the past ten years. However, local and regional differences in development are possible. No other trend is expected for the coming years.	+ 0.5
↑	Positive	In the past ten years, the increase in the total area of these types of habitats as a whole, or at least in large parts of the area, is likely to continue in the next few years.	+ 1.0
?	Data Deficient	Classification not possible	no change in threat category
#	Evaluation not reasonable	Types of habitats showing declining tendencies, but are 'undesirable' from the point of view of nature conservation.	no change in threat category

one single event or a critical hazard could destroy the whole inventory (cf. Williams et al. 2015). In the German procedure criterion R functions as a regulating upgrading factor. The main objective of this assessment is to emphasise the higher risk of loss of extremely rare habitats. A similar approach was introduced by Kontula and Raunio (2009), even though thresholds and the degree of differentiation differ due to the specificity of national data sources and natural conditions. The IUCN sets graded thresholds of 'restricted geographic distribution' which are only decisive if defined threat conditions are given (e.g. continuing decline, inferred threatening processes, low number of locations) (IUCN 2016).

Criterion R is not classified in a full system from widespread to extremely rare. All types of habitats are examined and classified as either 'Extremely Rare' or 'Not Extremely Rare'. All types which had been assessed as category 'R' (extremely rare) for the Red List status in the second edition (Riecken et al. 2006) were transferred to the category 'Extremely Rare' of criterion R. Furthermore, extremely rare types of habitats were derived from the area sums of the related Natura 2000 habitat types from the national report of 2013 (Ellwanger et al. 2015) (reporting obligation under Article 17 of the EU Habitats Directive). A maximum threshold for 'Extremely Rare' in terms of area size was set at a total area of 500 hectares in Germany. The corresponding assessment tightens RLG by half a value (Fig. 2, step 4).

Summary of symptoms of risk – Risk of Loss

RLG describes the overall 'Risk of Loss' under current national threat conditions. Based on nTH, criteria T and R have a downgrading or an upgrading effect (Fig. 2, step 5). All possible evaluation constellations are defined in the assessment scheme (Table 3). In principle, only long-term endangered habitat types and types classified in the early warning stage are taken into account in the assessment scheme. For non-

Table 3. Assessment scheme for determining the German Red List status (RLG). For the overall classification, three criteria are applied stepwise from left to right (National Long-term Threat [nTH], Current Trend [T], Rarity [R]).

Criterion I		Criterion II		Change in category	Interim value	Criterion III		Change in category	RLG
National Long-term Threat	0		→	+/-0	0		n/s		0
	1	Current Trend	↓	-0.5	1!	Rarity	x	-0.5	1!
							–		1!
			→	+0.5	1–2		x	-0.5	1
							–		1–2
			#, ?	+/-0	1		x	-0.5	1!
							–		1
			↑	+1	2		x	-0.5	1–2
							–		2
	2	Current Trend	↓	-0.5	1–2	Rarity	x	-0.5	1
							–		1–2
			→	+0.5	2–3		x	-0.5	2
							–		2–3
			#, ?	+/-0	2		x	-0.5	1–2
							–		2
			↑	+1	3		x	-0.5	2–3
							–		3
	3	Current Trend	↓	-0.5	2–3	Rarity	x	-0.5	2
							–		2–3
			→	+0.5	3–V		x	-0.5	3
							–		V–3
			#, ?	+/-0	3		x	-0.5	2–3
							–		3
			↑	+1	V		x	-0.5	V–3
							–		V
	V	Current Trend	↓	-0.5	3–V	Rarity	x	-0.5	3
							–		V–3
			→	+/-0	V		x	-0.5	V–3
							–		V
			#, ?	+/-0	V		x	-0.5	V–3
							–		V
			↑	+1	*		x	-0.5	V
							–		*
	*	Categories are not changed by the evaluation scheme							
	?								
	#								

endangered types, types with unknown threat-status, and types not relevant for nature conservation purposes, nTH corresponds to RLG. Due to the algorithm used, intermediate values can also occur. The stepwise assessment results in a wider spread of Red List categories (Table 4). The (verbal-descriptive) definitions of the Red List categories are derived from the possible combinations of the individual criteria according to the evaluation scheme (see Tables 1, 2).

The categories 'Imminently Threatened By Complete Destruction' (1!) and 'Imminently Threatened' (V–3) are newly introduced. These new categories represent both extremes of 'collapse risk' in the German approach.

Table 4. Categories of the German Red List status (RLG). The (verbal-descriptive) definitions of the Red List categories are derived from the possible combinations of the individual criteria according to the evaluation scheme (see Table 1, 2). The categories 'Imminently Threatened By Complete Destruction' (1!) and 'Imminently Threatened' (V–3) are newly introduced. These new categories represent both extremes of 'collapse risk' in the German approach.

German Red List status (RLG) Category	Description
0	Collapsed (CO)
1!	Imminently Threatened By Complete Destruction
1	Critically Endangered (CR)
1–2	Endangered (EN) to Critically Endangered (CR)
2	Endangered (EN)
2–3	Vulnerable (VU) to Endangered (EN)
3	Vulnerable (VU)
3–V	Imminently Threatened
V	Near Threatened (NT)
*	Least Concern (LC)
#	Evaluation not reasonable
?	Data Deficient (DD)

Results of the first-time application of the Assessment scheme

German Red List of Habitats 2017

The revised assessment system has been tested and applied in the current edition of the 'German Red List of threatened habitats' (Finck et al. 2017) (Table 5). The assessment covers a total of 863 marine, coastal, inland water, open terrestrial, shrubs/trees/forests, and alpine types of habitats in Germany (not considering so called 'technical habitats'). While two-thirds (65.1%, n = 562) of the assessed habitat types were assigned with different degrees of 'risk of loss' (Red List categories '0' to '3–V'), 24.7% (213) are currently of 'Least Concern'. Thirteen marine types of habitats (1.5%), mainly characterised by the European oyster (*Ostrea edulis*) or Honeycomb worm reefs (*Sabellaria* sp.), had to be classified as 'Collapsed' (category 0). Comparing the main habitat groups in Germany, the proportion of threatened coastal habitats (RLG categories 0 to 3–V) is the highest (82.8%). Alpine (58.8%) and marine (52.5%) habitat types represent the least threatened habitat groups. Inland waters (76.4%), open terrestrial habitats (68.8%), and shrubs/trees/forests (69.5%) show proportions of threatened habitat types above the average (65.1%). Open terrestrial habitats represent a significant proportion of habitat types classified in the highest threat category '1!' (16.3%). Intensive land use still represents the main threat factor especially for open terrestrial habitats and (to a lesser extent) forest habitats. A detailed analysis of major threat factors for habitat types in Germany was published in 2019 (Heinze et al. 2019).

Effects of applying the new assessment scheme

The application of the assessment scheme results in a clear spread of the realised categories for the Red List-status. Only a total of 101 (17.1%) of the long-term

Table 5. Assessment results for RLG 2017 (Finck et al. 2017). Number and proportions of habitat types assessed in the categories of German Red List status are given by the main groups of habitat types. Cat = Red Listing Category; T = Number of Types.

Cat RLG	Marine habitats		Coastal habitats		Inland waters		Open terrestrial habitats		Shrubs, trees & forests		Alpine habitats		All habitats (minus tech.)		Technical habitats[†]		All habitats	
	T	%	T	%	T	%	T	%	T	%	T	%	T	%	T	%	T	%
0	13	4.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	**13**	**1.5**	0	0.0	13	1.4
1!	3	1.1	4	6.9	7	5.7	33	16.3	3	2.0	2	3.9	**52**	**6.0**	0	0.0	52	5.5
1	3	1.1	2	3.4	8	6.5	3	1.5	4	2.6	1	2.0	**21**	**2.4**	0	0.0	21	2.2
1–2	3	1.1	7	12.1	31	25.2	48	23.8	22	14.6	1	2.0	**112**	**13.0**	2	2.7	114	12.2
2	22	7.9	5	8.6	4	3.3	2	1.0	5	3.3	7	13.7	**45**	**5.2**	0	0.0	45	4.8
2–3	28	10.1	13	22.4	24	19.5	38	18.8	43	28.5	4	7.8	**150**	**17.4**	6	8.0	156	16.6
3	19	6.8	3	5.2	3	2.4	1	0.5	2	1.3	1	2.0	**29**	**3.4**	0	0.0	29	3.1
3–V	55	19.8	14	24.1	17	13.8	14	6.9	26	17.2	14	27.5	**140**	**16.2**	4	5.3	144	15.4
V	20	7.2	3	5.2	1	0.8	2	1.0	1	0.7	1	2.0	**28**	**3.2**	0	0.0	28	3.0
*	80	28.8	7	12.1	24	19.5	51	25.2	32	21.2	19	37.3	**213**	**24.7**	21	28.0	234	24.9
?	9	3.2	0	0.0	0	0.0	0	0.0	0	0.0	1	2.0	**10**	**1.2**	0	0.0	10	1.1
#	23	8.3	0	0.0	4	3.3	10	5.0	13	8.6	0	0.0	**50**	**5.8**	42	56.0	92	9.8
Σ (all)	278	100	58	100	123	100	202	100	151	100	51	100	**863**	**100**	75	100	938	100
Risk of Loss (Σ cat. 0 to 3–V)	146	52.5	48	82.8	94	76.4	139	68.8	105	69.5	30	58.8	**562**	**65.1**	12	16	574	61.2

[†] Technical habitats: Group of anthropogenic habitats (e.g. buildings, roads, landfills) which have generally less significance for nature conservation. In special cases they can function as substitute habitats for species which are adapted to habitat conditions of settlement areas. Threats to this habitat group are mostly characterised by intensification of usage (e.g. sealing), restoration or demolition of old, historic buildings.

endangered habitat types (nTH = 0, 1, 2, 3, V) were classified in the same category for the overall RLG-status (Fig. 4). The newly introduced categories '1!' and '3–V' are frequently used: 16.2% of all assessed habitat types were classified in category '3–V'. 6% had to be assessed in category '1!' (Table 5). Two thirds of the habitat types, which are valued as 'Critically Endangered' (1) for nTH had to be upgraded to the category '1!' for RLG (Fig. 4, second bar). In contrast, almost 60% of habitat types that were assessed as 'Vulnerable' (3) according to nTH could be downgraded to category '3–V' or V, respectively, as they had a stable or positive short-term trend (Fig. 4, fourth bar).

Case study – raised bogs

The IUCN criteria catalogue (Keith et al. 2013) was applied to the national situation in Germany for raised bogs by Riecken et al. (2013). The overall status was assessed to be 'Critically endangered'. This result corresponded exactly to the national assessment at that time (Riecken et al. 2006). The condition of bogs is even better represented by the new methodology. The degradation started at the beginning of industrialisation during the 18th century, especially in the North-western lowlands of Germany but also in other parts of Europe. Bogs were drained and the peat was cut, dried, and trans-
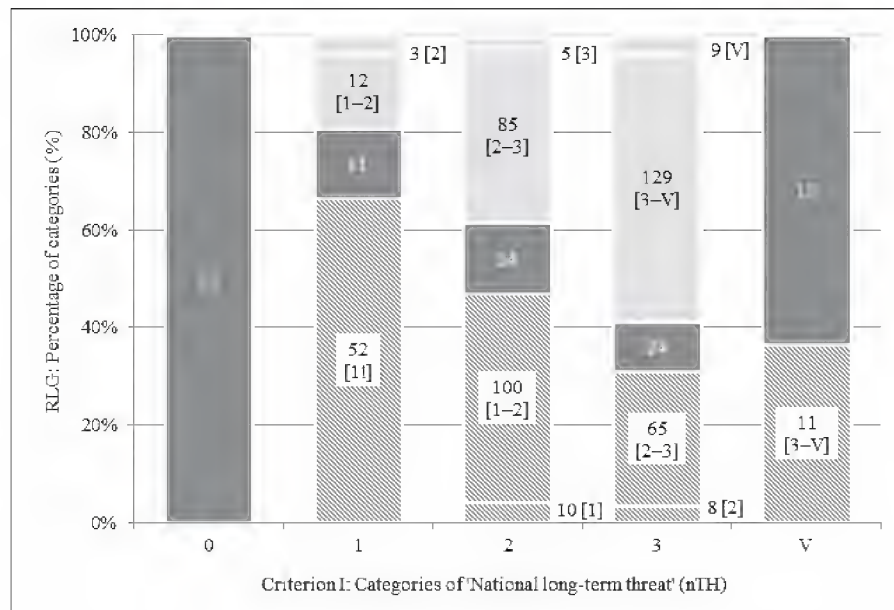
Figure 4. Spread of RLG-values (y-axis) by applying the matrix algorithm (Table 3). The analysis is based on nTH (criterion I, x-axis) for habitat types in Germany. Full dark pigmented bar = no change in category; full light-coloured bar = downgrading of threat category value; brindled bar = upgrading of threat category value; Labels: number of attributive habitat-types in the [resulting RLG-category].

ported so that only about 1–2% of the original area is preserved today (LLUR 2012; Ellwanger et al. 2015). The remaining sites are of relatively small size and isolated from other stocks. In the assessment period of the current edition of the German Red List, the long-term threat situation (rTH) of 'raised bogs' did not change significantly in most landscape regions (Table 6). Nevertheless, agricultural utilisation of former bogs continues and has increased in intensity during recent decades (Rath and Buchwald 2010). Additionally, climate-induced changes in abiotic conditions are having an increasingly negative impact (Essl and Rabitsch 2013). Therefore, T is still classified as negative. Applying the new assessment scheme, RLG had to be upgraded to the highest threat category ('1!'). Compared to the European assessment (Janssen et al. 2016), the situation in Germany is much more critical (European assessment [EU 28] for the decisive criterion A3/historical decline: EN). For the evaluation of the revised assessment of 'raised bogs', it must be considered that 'raised bogs' are characterised by very slow regeneration ability ('RE', Table 6, symbol 'N'). The regeneration ability was estimated for each habitat type. The result is 'additional information' and does not influence the assessment of the degree of threat (Blab et al. 1995). For this reason, no major improvements in the 'Long-term threat' can be expected in the near future. Only limited areas are available for bog restoration in Germany. With these preconditions, 'raised bogs' may always remain in a high long-term risk category in Germany. Criterion T was integrated into the evaluation process in order to be able to display current trends. The method-inherent increased Red List status in 2017 reveals an acute need for action to counteract specific causes of threat. Differences in the rTH show that the situation for characteristic habitat-subtypes in the North-western and North-eastern lowlands and the highland regions is even worse than for (subtypes of) the alpine region. Especially in the Alps, impacts of climate change and anthropogenic use can be observed, but so far have not changed the threat situation of 'raised bogs'. However, there may be a threshold for observable detriments, which has not yet been reached.

Table 6. Red List assessment for 'raised bogs' and Beech (mixed) forest in 2017. Regional Red List categories are presented for all major landscape regions. Code – hierarchical coding for database applications; A – Areas Loss; QU – Quality Loss; rTH – Regional Long-term Threat; nTH – National Long-term Threat; T – Current Trend; RLG – German Red List status; RE – Regeneration Ability: B-K – regeneration 'conditionally possible' to 'hardly possible'; N – 'not regenerable'; Major landscape region (see Blab et al. 1995): NW-Low – North-western lowlands; NE-Low – North-eastern lowlands; W-Upl. – Western highlands; E-Upl. – Eastern highlands; SW-Upl. – South-western highlands; Alp. Fh. – Alpine foothills; Alps – Alps * intermediate values are no longer used for nTH in 2017.

Code	Habitat-Type	NW-Low			NE-Low			W-Upl.			E-Upl.			SW-Upl.			Alp. Fh.			Alps			nTH 2006	nTH 2017	T 2006	T 2017	RLG 2017	RE
		A	QU	rTH	A	QU	rTH	A	QU	rTH	A	QU	rTH	A	QU	rTH	A	QU	rTH	A	QU	rTH						
36.01	Raised bogs (largely intact)	1	1	**1**	1	1	**1**	1	1	**1**	1	2	**1**	1	1	**1**	2	2	**2**	2	3	**2**	1	1	↓	↓	1!	N
43.07.04	Beech (mixed) forest on moist, base-deficient sites	2	2	**2**	3	3	**3**	2	3	**2**	3	3	**3**	2	3	**2**	2	3	**2**	3	3	**3**	2–3*	2	↑	↑	3	B-K

Case study – beech forests

In the German habitat classification used for the Red List, pristine woods are not separated but are assessed together with their utilized variants. There is no database available which describes different pristine Central European forest types in detail. The risk assessment of forest habitat types therefore represents a weighted median of the existing stands (structure-rich old-forest, young age-class forest, etc.). The degree of naturalness (richness of structure, mixed forest, old wood, deadwood, stratification of different age classes) is weighted by the risk assessment through the quality criterion (QUL). In many cases, the specific ground layer is also well-developed in woodland areas which are used by forestry, so that a classification of the forest habitat type is possible. The Long-term Threat to 'beech (mixed) forests on moist, base-deficient sites (*Fagus sylvatica*)' has not changed since the last assessment period and is still classified as being 'Endangered (EN/2)'. Thus, the continued positive short-term trend has not yet affected the long-term threat assessment. However, this type is experiencing an improvement of a full threat category from EN (2) to VU (3) for RLG (Table 6) as the area of beech forests in Germany has been continuously increasing in recent decades. A general reorientation in forest management in recent decades has contributed to a significant increase in native broadleaved forests in Germany (BMEL 2016). Former main threats such as 'reforestation with non-autochthonous trees' have decreased, at least in protected areas. The current downgrading of the Red List status reflects these efforts. Nevertheless, the legal protection of beech forests within Natura 2000 sites may not be sufficient to reach biodiversity goals if intensive forestry continues in large parts of protected areas (Panek 2016). Therefore, programmes were initiated to increase non-intervention management areas (e.g. EU Biodiversity Strategy, National Strategy on Biological Diversity). To continue the positive development, additional focus must be set on the habitat quality as well.

Discussion, conclusions and perspectives

The following discussion focuses on terrestrial and limnic habitats, as more detailed knowledge about most marine habitats has only recently become available.

Dealing with data availability

In contrast to the Red Lists of species, the underlying data for habitat threat are not collected by volunteer scientists but exclusively in the context of monitoring obligations (e.g. EU Habitats Directive) or in the course of habitat mapping by the federal states. Thus, the national Red List assessment in Germany mostly relies on regional data sources collected by federal state administrations. Marine habitats are an exception, because here the German Federal Agency for Nature Conservation is the directly responsible nature conservation authority. Data collection in the 'Exclusive Economic Zone' is therefore carried out by the Federal Government and in coastal areas by the Federal States. Even though data from current habitat mappings were not available for all federal states in the current Red List, the existing baselines provides a good overview of all major landscape regions (see Fig. 3). However, there are still considerable differences in the actuality, evaluation and mapping methodology (Kaiser et al. 2013). In addition, classification systems of habitat types of the sixteen federal states are not completely comparable. For this reason, data originating from federal states often cannot be transferred directly. Thus, a supplementary, case-by-case expert assessment was often necessary up to now. However, there are approaches to minimise problems with data availability and transferability. On the one hand, there are efforts on the part of the federal states to standardise mapping (e.g. in a benchmark paper; Beck et al. 2013). On the other hand, a universally applicable standard list of habitat types is being developed in a current research project which aims to establish a nationwide, uniform random sample of habitat mapping (BfN 2018). This will make it easier to match the data originating from the federal states in the future. In addition, the planned nationwide random samples would represent a kind of calibration. The establishment of frequent, standardised ecosystem monitoring could function as a solid regular database for the assessment of changes in the actual threat situation of many habitat types. Great efforts have also been made in recent years in the classification and monitoring of marine habitat types (Finck et al. 2017; BfN 2019). There is still a lack of national standardised monitoring data for a wide range of habitat types occurring in Germany and Europe. However, through the monitoring obligations of the EU Habitats Directive, a standardised tool is available at least for habitats which correspond to types in Annex I of the Directive. Nevertheless, it is not always possible to assign the types defined in the Habitats Directive directly to the German standard list of habitats due to different definitions or development goals. A crucial question remains: to what extent the habitat data, which were collected under the Habitats Directive, can be used to draw conclusions about the current frequency, distribution,

and quality of habitat types within the framework of the national Red List. At least we tried to keep the European types as distinct as possible in order to guarantee a transferability of the data into the German standard list. Nonetheless, summarising the given data into a nationwide Red list is usually a standardisation step for which expert assessment remains necessary.

Comparisons with the previous edition of the Red List (Riecken et al. 2006) are only possible to a limited extent for the individual criteria due to the changed evaluation methodology. Unfortunately, changes in methodology are always at the expense of comparability; at least the determination of the individual criteria nTH and T was kept unchanged.

Relevance of a historic reference value

As a first step in our assessment procedure the long-term threat situation in area and quality is always assessed – if detailed databases are lacking –, based on expert estimation. In today's intensively cultivated landscape, we can assume that the historical conditions of many habitat types with significance for biodiversity were more favourable. Therefore, a comparison with the 'historical *more* ideal condition' of habitat types is the starting point of our Red List assessment. This rationale can be confirmed by the application of IUCN criteria for the 'European Red List of Habitats' (Janssen et al. 2016). In some European countries, only limited data for long-term trends were available, so that criterion A3 (reduction in geographic distribution since 1750) was assessed as being 'data deficient' (cf. Janssen et al. 2016; Biró et al. 2017). Following the 'precautionary principle', the resulting Red List category is therefore based on one or two criteria which often only reflect short-term threat situations and can therefore be misleading to an overrated positive or negative evaluation compared to the 'historical condition' of the habitat. For some habitat types the reference period already reveals a depleted situation. In a study from Hungary, Biró et al. (2017) have shown that the number of highly endangered habitat types increase dramatically if the long-term trend is taken into account. To deal with the possibility of 'earlier decline', Kontula and Raunio (2009) proposed tightening the assessment in a sub-step of their stepwise procedure (here criterion A3, B3). Since 'early decline' represents a temporal shift in the historical 'ideal state' for particular habitat types, this factor is taken into account in the long-term assessment of the German procedure by setting a sliding time frame. Thus, the selection of an adequate historical reference period for Red List assessments is also a question of the specific history of landscape development, as well as national nature conservation objectives. In Germany, for example, the preservation of extensively used semi-natural habitat types is a legal objective regulated in the Federal Nature Conservation Act. This is one of the reasons why we chose a later and dynamic long-term reference period than the IUCN. Since habitats are dynamic systems, which typically do not disappear but rather replace each other, vulnerability must be assessed individually for each type. For this reason, we state that reference periods (particularly

long-term evaluations) can also differ for habitat groups. Overrated positive evaluations through the IUCN method may particularly apply to European forest habitats, which have experienced severe historical losses but are currently increasing or stable (see case study beech forests).

Signal effect of the short-time control value

By extending the criteria system, RLG is particularly intended to reveal successes in nature conservation and the need for action. In this context, we agree with the argumentation of Delarze et al. (2016), that the objective of national Red Lists is to demonstrate current trends and to indicate needs for action. This effect becomes clear in various ways by analysing the results of the current German Red List. For example, in an alarming way, many of the open terrestrial habitats were assigned to the highest threat category '1!' (16.3%, Table 5). There is still an ongoing negative trend, especially for many terrestrial open landscape habitat types, mainly caused by the intensification of agriculture accompanied by grassland loss and levelling of site conditions, which results in a severe loss of extensively used rural habitats (Heinze et al. 2019). The loss of biodiversity in the cultural landscape is also a topical issue in European politics. Here the result of the Red List fits into the general picture. The Common Agricultural Policy severely impacts biodiversity and ecosystem services (Simoncini et al. 2019). The "Red List tool" must therefore also be able to reveal short-term changes in intensively used landscapes, which can change very quickly due to initial agricultural policy conditions.

The urgent need for an accentuation of "critically endangered" as well as currently declining habitat types is clearly illustrated by case study of raised bog ecosystems. On the other hand, widespread beech forest habitat types are experiencing an improvement of a full threat category from EN (2) to VU (3) for RLD, as the area of beech forests is continuously increasing (see case study) in recent decades. To show actual tendencies by means of the Red List category, short-term trends function to illustrate modification in the threat situation. Generally, habitats which are characterised by very slow regeneration ability, which have been severely destroyed or deteriorated in historical times (e.g. forest types, raised bogs cf. case studies), can only achieve minor improvements in their 'National Long-term Threat' (nTH) status. Once severely degraded, the period of time required for re-establishing defining features may exceed the reference period of Red List assessments. By using a consecutive assessment scheme, a change in the Red List status is possible even if the long-term threat remains the same. Applying the assessment procedure of previous German Red Lists, a change in the Red List status of a habitat type was only possible if a significant change in the threat situation was achieved with the historical optimum state as a reference.

Overall, the approach of assessing stable trends as (first) successes in nature conservation and therefore with a reduction of the overall threat has proven successful. Otherwise, the current extinction risk for extremely rare but currently stable habitat

types that are endangered in the long term would be overestimated when applying the assessment scheme. In nature conservation, the short-term focus should be on the many habitat types that are currently in decline. In the intensively used European cultural landscape, maintaining the same conditions of conservation is also a (small) success. This approach is also laid down in the EU Habitats Directive, whereby a ban on deterioration of the conservation status of habitat types is taken as the minimum objective (Council of the European Communities 1992). However, a long-term goal must also be the improvement of conservation status or rather a "Least Concern" condition. In general, since continuous short-term trends have a long-term effect only after several decades, criterion T functions as a short-time control value. However, the preceding interpretations should be seen with the limitation that the actual impact of the signal effect of RLG through the integration of short-term changes for the necessity of nature conservation action can only be evaluated when regular assessments of the endangerment of Germany's habitat types are available. By comparing Red List versions, it will be possible in future to map actual developments and thus initiate direct nature conservation measures towards habitats with negative developments. In order to exactly reflect the development in the update cycle of ten years, introduction of two sub criteria of T should be considered, looking ten years into the past on the one hand and ten years into the future on the other (corresponding to the parameter 'future prospects' in Habitat Directive assessments of conservation status). As a result, if repeated assessments are available (as in Germany), short time tendencies become particularly relevant for management decisions.

Influence of rarity

Extremely rare habitat types are naturally exposed to a higher risk of severe impairment by individual events (Finck et al. 2017). In the German Red List, the assessment scheme only includes threatened (and near threatened) habitats, so that corresponding conditions were examined before criterion R could have any effect on RLG. Thus, our approach prevents misleading evaluations of naturally extremely rare habitats which are actually not decreasing or degrading (c.f. Gigante et al. 2016). Because rarity has a further aggravating effect in our assessment, extremely rare but currently stable types do not easily lose the focus of nature conservation.

Bland et al. (2017) have the reverse approach, so that thresholds of 'restricted geographic distribution' are only decisive if special threat conditions are given (e.g. continuing decline, inferred threatening processes, low number of locations). The criterion of rarity in our approach is so far a yes/no criterion. On the basis of the available data, it should be analysed in more detail as to whether further differentiation of this criterion makes sense in future. A differentiation among various types of habitats would be more appropriate. For example, 500 hectares of Alpine rivers cannot be compared to 500 hectares of beech forests, merely from the surface area point of view.

Future prospects

The assessment system applied to the third edition of the German Red List relies on a full assessment of all criteria and a use of all individual values to determine RLG. In contrast, in the IUCN procedure the highest risk category obtained by any of the assessed criteria represents the overall risk status. Nevertheless, all three criteria of the German methodology indicate spatial changes as symptoms of 'ecosystem collapse' (c.f. Bland et al. 2017; Rowland et al. 2018). The change in quality is also assessed in the case of criterion nTH. However, the effect of individual criteria can deviate greatly from each other (Finck et al. 2017). Therefore, in our opinion, the overall 'risk of loss' can only be assessed by taking all criteria into consideration.

Some recently published European Red List assessments (e.g. Härtel et al. 2009 [CZ]; Essl and Egger 2010 [AT]; Biserkov et al. 2015 [BU]; Finck et al. 2017 [DE]) do not strictly follow the IUCN approach, which has been significantly developed since 2009 (Keith et al. 2009). However, in most of these lists the early draft of the IUCN approach was considered. At least the basic concept of 'ecosystem collapse' has also been applied in the German method. The assessment procedure presented here allows for a clearly defined differentiated assessment of the overall 'risk of loss' (Keith et al. 2009) for individual habitat types under current threat conditions. In principle it has been shown that IUCN criteria for Red List assessment of habitats are applicable within small countries or regions (Bland et al. 2019). Some countries use already an assessment procedure very close to the methodology proposed by the IUCN (e.g. Lindgaard and Henriksen 2011; Delarze et al. 2015, 2016; Gubbay et al. 2016; Janssen et al. 2016; Kontula and Raunio 2019; Chytrý et al. 2019). However, they also had to allow for national or European specifications of the IUCN protocol (e.g. workshop documentation; Finnish Environment Institute 2019). In addition, it is often the case that only some of the IUCN criteria could be evaluated, which can lead to incomplete and sometimes inconclusive risk assessments (see case studies). A detailed comparison of the assessments of these lists is not the subject of this paper. However, in this context the objective of habitat red-listing must be discussed, considering the background of nature conservation goals (see also Delarze et al. 2016; Gigante et al. 2018; Bland et al. 2019; Rowland et al. 2019).

Ultimately, a 'standard criteria system' should offer sufficient flexibility to adapt to national and regional requirements. In this regard, we may need to discuss different thresholds and reference time frames for different habitat groups depending on specific spatial pattern and distribution history. For example, Delarze et al. (2016) have lowered the thresholds for IUCN criteria B1 and B2 in view of the relatively small size of the country. A future prospect will be to integrate useful national approaches to international standards. Since the distribution of ecosystems may extend over different countries (evaluation units), threats to specific ecosystems or habitat types should be determined in a broader spatial scale with the precondition that evaluation systems are comparable. However, this proposal is limited by the actual availability of significant data for the assessed area, which determines the applicability of criteria. Analogous

to the improvement of data sources the catalogue of criteria and categories should be adapted and improved. Modifications to apply the IUCN criteria for Red List assessment are a realistic response to the amount of available data for a landscape that is highly diverse, fine-grained and dynamic, as well as strongly affected by cultural influences (cf. Janssen et al. 2016).

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References

Agnoletti M, Rotherham ID (2015) Landscape and biocultural diversity. Biodiversity and Conservation 24(13): 3155–3429. https://doi.org/10.1007/s10531-015-1003-8

Alaniz A, Perez-Quezada JF, Galleguillos M, Vásquez AE, Keith DA (2019) Operationalizing the IUCN Red List of Ecosystems in public policy. Conservation Letters 12(5): 1–11. https://doi.org/10.1111/conl.12665

Beck A, Bettinger A, Boedeker D, Von Drachenfels O, Essl F, Finck P, Gerstner H, Heidecke H, Hinterlang D, Kaiser T, Von der Lancken A, Ludwig G, Petersen W, Raths U, Remy D, Reusch H, Riecken U, Schleyer E, Schlumprecht H, Schröder E, Schuboth J, Schwabe-Kratochwil A, Stellmach M, Störger L, Uhlemann S, Zimmermann F (2013) Bedeutung landesweiter Biotopkartierungen in Deutschland: Ein Eckpunktepapier. Natur und Landschaft 88(3): 101–102. https://doi.org/10.17433/3.2013.50153208.97-102

BfN [Bundesamt für Naturschutz] (2010) Karte der Potentiellen Natürlichen Vegetation Deutschlands. Maßstab 1:500.000. Landwirtschaftsverlag, Münster, 24 pp.

BfN [Bundesamt für Naturschutz] (2017) Determination of the Red List status (RLD), from Finck et al. 2017 (modified). https://www.bfn.de/en/activities/red-list/rl-biotoptypen/aus-marginalspalte/kriterien-und-kategorien.html

BfN [Bundesamt für Naturschutz] (2019) Marine-Monitoring. https://www.bfn.de/en/activities/marine-nature-conservation/marine-monitoring.html

BfN [Bundesamt für Naturschutz] (2018) Ökosystem-Monitoring. https://www.bfn.de/themen/ monitoring/oekosystem-monitoring/

Biró M, Bölöni J, Molnár Z (2017) Use of long-term data to evaluate loss and endangerment status of Natura 2000 habitats and effects of protected areas. Conservation Biology 32(3): 660–671. https://doi.org/10.1111/cobi.13038

Biserkov V, Gussev Ch, Popov V, Hibaum G, Roussakova V, Pandurski I, Uzunov Y, Dimitrov M, Tzonev R, Tsoneva S [Eds] (2015) Red Data Book of the Republic of Bulgaria (Vol. 3). Natural Habitats. Institute of Biodiversity and Ecosystem Research, Sofia, 422 pp.

Blab J (1984) Grundlagen des Biotopschutzes für Tiere:Ein Leitfaden zum praktischen Schutz der Lebensraeume unserer Tiere. Schriftenreihe für Landschaftspflege und Naturschutz 24: 1–205.

Blab J, Riecken U, Ssymank A (1993) Vorschlag eines Kriteriensystems für eine Rote Liste Biotope auf Bundesebene. In: Blab J, Riecken U (Eds) Grundlagen und Probleme einer Roten Liste der gefaehrdeten Biotoptypen Deutschlands: Referate und Ergebnisse. Schriftenreihe für Landschaftspflege und Naturschutz 38: 265–273.

Blab J, Riecken U, Ssymank A (1995) Proposal on a criteria system for a national Red Data Book of Biotopes. Landscape Ecology 10(1): 41–50. https://doi.org/10.1007/BF00158552

Bland LM, Keith DA, Miller RM, Murray N, Rodríguez JP (2017) Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria. Version 1.1. IUCN, Gland. https://doi.org/10.2305/IUCN.CH.2016.RLE.3.en

Bland LM, Rowland J, Regan T, Keith DA, Murray N, Lester R, Linn M, Rodríguez JP, Nicholson E (2018) Developing a standarized definition of ecosystem collapse for risk assessment. Frontiers in Ecology and the Environment 16(1): 29–36. https://doi.org/10.1002/fee.1747

Bland LM, Nicholson E, Miller RM, Andrade A, Etter A, Ferrer-Paris JR, Kontula T, Lindgaard A, Pliscoff P, Skowno A, Zager I, Keith DA (2019) Impacts of the IUCN Red List of Ecosystems on conservation policy and practice. Conservation Letters 12(5): e12666. https://doi.org/10.1111/conl.12666

BMEL (Bundesministerium für Ernährung und Landwirtschaft) (2016) Der Wald in Deutschland. Ausgewählte Ergebnisse der dritten Bundeswaldinventur. 2. korrigierte Auflage. BMEL 2015: 1–52. https://www.bmel.de/SharedDocs/Downloads/EN/Publications/ForestsInGermany-BWI.pdf?__blob=publicationFile

Buder W, Uhlemann S (2010) Biotoptypen: Rote Liste Sachsens (3th edn.). Landesamt für Umwelt, Landwirtschaft und Geologie, Dresden, 140 pp. https://publikationen.sachsen.de/bdb/artikel/11947

Chytrý M, Hájek M, Kočí M, Pešout P, Roleček J, Sádlo J, Šumberová K, Sychra J, Boublík K, Douda J, Grulich V, Härtel H, Hédl R, Lustyk P, Navrátilová J, Novák P, Peterka T, Vydrová A, Chobo K (2019) Red List of Habitats of the Czech Republic. Ecological Indicators 106: 105446. https://doi.org/10.1016/j.ecolind.2019.105446

Council of the European communities (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal L 206: 0007–0050. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1992:206:0007:0050:EN:PDF

Delarze R, Gonseth Y, Eggenberg S, Vust M (2015) Lebensräume der Schweiz: Ökologie – Gefährdung – Kennarten (3rd edn.). Ott, Bern, 456 pp.

Delarze R, Eggenberg S, Steiger P, Bergamini A, Fivaz F, Gonseth YG, Hofer G, Sager L, Stucki P (2016) Rote Liste der Lebensräume der Schweiz. Aktualisierte Kurzfassung zum technischen Bericht im Auftrag des Bundesamtes für Umwelt, Bern, 32 pp.

DG Environment (Directorate-General for Environment) (2017) Reporting under Article 17 of the Habitats Directive: Explanatory notes and guidelines for the period 2013–2018. DG Environment, Brussels, 187 pp. http://cdr.eionet.europa.eu/help/habitats_art17

Dimopoulos P, Bergmeier E, Fischer P (2005) Monitoring and conservation status assessment of habitat types in Greece: Fundamentals and exemplary cases. Annali di Botanica nuova serie 5: 7–20. DOI: https://doi.org/10.4462/annbotrm-9207

Doniţă N, Popescu A, Paucă-Comănescu M, Mihăilescu S, Biriş IA (2005) Habitatele din România. Editura Tehnică Silvică, Bucureşti, 496 pp.

Ellwanger G, Raths U, Benz A, Glaser F, Runge S [Eds] (2015) Der nationale Bericht 2013 zur FFH-Richtlinie: Ergebnisse und Bewertung der Erhaltungszustände. Teil 1 – Die Lebensraumtypen des Anhangs I und allgemeine Berichtsangaben auf Grundlage von Daten der Länder und des Bundes. Bundesamt für Naturschutz (Bonn). BfN-Skripten 421(1): 1–417.

Erz W (1971) Landschaftsplanung, Tierökologie und Biotopgestaltung. Natur und Landschaft 46(8): 203–206.

Essl F, Egger G (2010) Lebensraumvielfalt in Österreich – Gefährdung und Handlungsbedarf: Zusammenschau der Roten Liste gefährdeter Biotoptypen Österreichs. Sonderpublikation. Naturwissenschaftlicher Verein für Kärnten, Klagenfurt, 111 pp.

Essl F, Rabitsch W (2013) Biodiversität und Klimawandel. Auswirkungen und Handlungsoptionen für den Naturschutz in Mitteleuropa. Springer Spektrum, Berlin/Heidelberg, 458 pp. https://doi.org/10.1007/978-3-642-29692-5

Essl F, Egger G, Ellmauer T (2002) Rote Liste gefährdeter Biotoptypen Österreichs. Konzept. Umweltbundesamt (Wien). Monographien Band 155: 1–40.

Finck P, Heinze S, Raths U, Riecken U, Ssymank A (2017) Rote Liste der gefährdeten Biotoptypen Deutschlands. Landwirtschaftsverlag (Münster). Naturschutz und Biologische Vielfalt 156: 1–637. https://doi.org/10.19213/973156

Finnish Environment Institute (2019) Workshop-documentation website. Workshop in Helsinki 29–30 October 2019: Red Lists of Ecosystems (RLE) in Europe – similarities and differences in approaches. https://www.ymparisto.fi/en-US/Nature/Natural_habitats/Assessment_of_threatened_habitat_types_in_Finland

Gigante D, Foggi B, Venanzoni R, Viciani D, Buffa G (2016) Habitats on the grid: The spatial dimension does matter for red-listing. Journal for Nature Conservation 3: 1–9. https://doi.org/10.1016/j.jnc.2016.03.007

Gigante D, Acost A, Agrillo E, Armiraglio S, Assini S, Attorre F, Bagella S, Bufa G, Casella L, Giancola C, Giusso GP, Marcenò C, Pezzi G, Prisco I, Venanzoni R, Viciani D (2018) Habitat conservation in Italy: The state of the art in the light of the first European Red List of Terrestrial and Freshwater Habitats. Rendiconti Lincei. Scienze Fisiche e Naturali 29(2): 251–265. https://doi.org/10.1007/s12210-018-0688-5

Gubbay S, Sanders N, Haynes T, Janssen JAM, Rodwell JR, Nieto A, Calix M, Sanders N, Saunders G, Micu D, Kennedy M (2016) European Red List of Habitats. Part 1: Marine habitats. European Commission, Brussels, 46 pp. https://doi.org/10.2779/032638

Härtel H, Lončáková J, Hošek M (2009) Mapování biotopů v České republice: Východiska, výsledky, perspektivy. Agentura ochrany přírody a krajiny ČR (AOPK), Praha. http://www.cetpo.upol.cz/knihovna/biologie/ekologie/

Heinze S, Finck P, Raths U, Riecken U, Ssymank A (2019) Analysis of major threat factors for habitat types in Germany. Natur und Landschaft 94(11): 453–462. https://doi.org/10.17433/11.2019.50153745.453-462

HELCOM (Helsinki-Kommission) (2013) Red List of Baltic Sea underwater biotopes, habitats and biotope complexes. Baltic Sea Environmental Proceedings 138 pp. https://www.helcom.fi/wp-content/uploads/2019/10/BSEP138.pdf

IUCN (2019) Recourses: Background. https://iucnrle.org/resources/background/

IUCN (International Union for Conservation of Nature) (2016) An Introduction to the IUCN Red List of Ecosystems: The Categories and Criteria for Assessing Risks to Ecosystems. IUCN, Gland. https://doi.org/10.2305/IUCN.CH.2016.RLE.2.en

Janssen JAM, Rodwell JS, García Criado M, Gubbay S, Haynes T, Nieto A, Sanders N, Landucci F, Loidi J, Ssymank A, Tahvanainen T, Valderrabano M, Acosta A, Aronsson M, Arts G, Attorre F, Bergmeier E, Bijlsma RJ, Bioret F, Biţă-Nicolae C, Biurrun I, Calix M, Capelo J, Čarni A, Chytrý M, Dengler J, Dimopoulos P, Essl F, Gardfjell H, Gigante D, Giusso del Galdo G, Hájek M, Jansen F, Jansen J, Kapfer J, Mickolajczak A, Molina JA, Molnár Z, Paternoster D, Piernik A, Poulin B, Renaux B, Schaminée JHJ, Šumberová K, Toivonen H, Tonteri T, Tsiripidis I, Tzonev R, Valachovič M (2016) European Red List of Habitats. Part 2. Terrestrial and freshwater habitats. European Commission, Brussels, 1–40. https://doi.org/10.2779/091372

Kaiser T, Schlumprecht H, Finck P, Riecken U (2013) Habitat mapping in the federal states of Germany – status and comparison of methodologies. Natur und Landschaft 88(3): 97–102. https://doi.org/10.17433/3.2013.50153208.97-102

Kaule G (1986) Arten- und Biotopschutz. Grosse Reihe. E. Ulmer, Stuttgart, 461 pp. https://doi.org/10.1007/BF02854827

Keith DA, Orscheg C, Simpson CC, Clarke PJ, Hughes L, Kennelly SJ, Major RE, Soderquist TR, Wilson AL, Bedward M (2009) A new approach and case study for estimating extent and rates of habitat loss for ecological communities. Biological Conservation 142(7): 1469–1479. https://doi.org/10.1016/j.biocon.2009.02.015

Keith DA, Rodríguez JP, Rodríguez-Clark KM, Aapala K, Alonso A, Asmussen M, Bachman S, Basset A, Barrow EG, Benson JS, Bishop MJ, Bonifacio R, Brooks TM, Burgman MA, Comer P, Comı'n FA, Essl F, Faber-Langendoen D, Fairweather PG, Holdaway RJ, Jennings M, Kingsford RT, Lester RE, Nally RM, McCarthy MA, Moat J, Oliveira-Miranda MA, Pisanu P, Poulin B, Regan TJ, Riecken U, Spalding MD, Zambrano-Martı'nez S (2013) Scientific foundations for an IUCN Red List of Ecosystems. PLoS ONE 8(5): e62111. https://doi.org/10.1371/journal.pone.0062111

Keith DA, Rodríguez JP, Brooks TM, Burgman MA, Barrow EG, Bland L, Comer PJ, Franklin J, Link J, McCarthy MA, Miller RM, Murray NJ, Nel J, Nicholson E, Oliveira-Miranda MA, Regan TJ, Rodr'ıguez-Clark KM, Rouget M, Spalding MD (2015) The IUCN Red List of Ecosystems: Motivations, challenges and applications. Conservation Letters 8(3): 214–226. https://doi.org/10.1111/conl.12167

Kontula T, Raunio A (2009) New method and criteria for national assessments of threatened habitat types. Biodiversity and Conservation 18(14): 3861–3876. https://doi.org/10.1007/s10531-009-9684-5

Kontula T, Raunio A [Eds] (2019) Threatened Habitat Types in Finland 2018. Red List of Habitats – Results and Basis for Assessment. Finnish Environment Institute and Ministry of the Environment (Helsinki). The Finnish Environment 2/2019: 1–254. http://hdl.handle.net/10138/308426

Lindgaard A, Henriksen S [Eds] (2011) The 2011 Norwegian Red List for Ecosystems and Habitat Types. Norwegian Biodiversity Information Centre, Trondheim. https://www.artsdatabanken.no/Pages/201624/Norwegian_Red_List_for_Ecosystems

LLUR (Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein) (2012) Potentiale und Ziele zum Moor- und Klimaschutz. Gemeinsame Erklärung der Naturschutzbehörden. LLUR (Flintbek). Schriftenreihe: LLUR SH – Natur 20: 1–37.

Ludwig G, Haupt H, Gruttke H, Binot-Hafke M (2009) Methodik der Gefährdungsanalyse für Rote Listen. In: Haupt H, Ludwig G, Gruttke H, Binot-Hafke M, Otto C, Pauly A [Eds] Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands. Band 1: Wirbeltiere. Landwirtschaftsverlag (Münster). Naturschutz und Biologische Vielfalt 70(1): 23–71.

Meynen E, Schmithüsen J [Eds] (1953–62) Handbuch der naturräumlichen Gliederung Deutschlands. Selbstverlag, Remagen, 1339 pp.

Panek N (2016) Deutschland deine Buchenwälder. Daten-Fakten-Analysen. Ambaum Verlag, Vöhl-Basdorf, 208 pp.

Petersen B, Ellwanger G, Biewald G, Hauke U, Ludwig G, Pretscher P, Schröder E, Ssymank A [Eds] (2003) Das europäische Schutzgebietssystem Natura 2000. Ökologie und Verbreitung von Arten der FFH-Richtlinie in Deutschland. Band 1: Pflanzen und Wirbellose. Landwirtschaftsverlag (Münster). Schriftenreihe für Landschaftspflege und Naturschutz 69(1): 1–743.

Petrella S, Bulgarini F, Cerfolli F, Polito M, Teofili C [Eds] (2005) Libro rosso degli habitat d'Italia della Rete Natura 2000. Schede, Roma. http://www.parchilazio.it/biblioteca-458-libro_rosso_degli_habitat_d_italia_della_rete_natura_2000

Rath A, Buchwald R (2010) Nutzung von Hochmoorgrünland in Nordwestdeutschland. Naturschutz und Landschaftsplanung 42(4): 108–114.

Raunio A, Schulman A, Kontula T [Eds] (2008) The assessment of threatened habitat types in Finland. Suomen ympäristö, 8/2008 Osa (1): 253–264.

Riecken U, Ries U, Ssymank A (1994) Rote Liste der gefährdeten Biotoptypen der Bundesrepublik Deutschland. Kilda-Verlag (Greven). Schriftenreihe für Landschaftspflege und Naturschutz 41: 1–184. https://doi.org/10.1002/9783527678471.hbnl2003006

Riecken U, Finck P, Raths U, Schröder E, Ssymank A (2003) Standard-Biotoptypenliste für Deutschland. 2. Fassung. Landwirtschaftsverlag (Münster). Schriftenreihe für Landschaftspflege und Naturschutz 75: 1–65.

Riecken U, Finck P, Raths U, Schröder E, Ssymank A (2006) Rote Liste der gefährdeten Biotoptypen Deutschlands. Zweite fortgeschriebene Fassung. Landwirtschaftsverlag (Münster). Naturschutz und Biologische Vielfalt 34: 1–318. https://doi.org/10.1002/9783527678471.hbnl2003006

Riecken U, Finck P, Raths U (2013) Raised bogs of Germany (National Assessment). In: Keith DA, Rodríguez JP, Rodríguez-Clark KM, Nicholson E, Aapala K, Alonso A, Asmussen M, Bachman S, Basset A, Barrow EG, Benson JS, Bishop MJ, Bonifacio R, Brooks TM, Burgman MA, Comer P, Comín FA, Essl F, Faber-Langendoen D, Fairweather PG, Holdaway RJ, Jennings M, Kingsford RT, Lester RE, Nally RM, McCarthy MA, Moat J, Oliveira-Miranda MA, Pisanu P, Poulin B, Regan TJ, Riecken U, Spalding MD, Zambrano-Martínez S (2013) Scientific foundations for an IUCN Red List of Ecosystems. Supplementary material. PLoS ONE 8(5): e62111. https://doi.org/10.1371/journal.pone.0062111

Rodríguez JP, Rodríguez-Clark KM, Baillie JEM, Ash N, Benson J, Boucher T, Brown C, Burgess ND, Collen B, Jennings M, Keith DA, Nicholson E, Revenga C, Reyers B, Rouget M, Smith T, Spalding M, Taber A, Walpole M, Zager I, Zamin T (2011) Establishing IUCN

Red List Criteria for Threatened Ecosystems. Conservation Biology 25(1): 21–29. https://doi.org/10.1111/j.1523-1739.2010.01598.x

Rodríguez JP, Keith DA, Rodríguez-Clark KM, Murray NJ, Nicholson E, Regan TJ, Miller RM, Barrow EG, Bland LM, Boe K, Brooks TM, Oliveira-Miranda MA, Spalding M, Wit P (2015) A practical guide to the application of the IUCN Red List of Ecosystems criteria. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 370(1662): 20140003. https://doi.org/10.1098/rstb.2014.0003

Rodwell JS, Janssen JAM, Gubbay S, Schaminée JHJ (2013) Red List Assessment of European Habitat Types. A feasibility study. Report for the European Commission, DG Environment, Contract No. 070307/2012/624047/SER/B3, Brussels.

Rowland JA, Nicholson E, Murray NJ, Keith DA, Lester RE, Bland LM (2018) Selecting and applying indicators of ecosystem collapse for risk assessments. Conservation Biology (32): 233–245. https://doi.org/10.1111/cobi.13107

Rowland JA, Bland LM, Keith DA, Juffe-Bignoli D, Burgman MA, Etter A, Ferrer-Paris JR, Miller RM, Skowno AL, Nicholson E (2019) Ecosystem indices to support global biodiversity conservation. Conservation Letters 2019: e12680. https://doi.org/10.1111/conl.12680

Savio L, Gaudillat V (2015) Synthèse des expériences européennes et françaises de Listes Rouges écosystémiques. Version 2. Rapport SPN 2015/35. MNHN-DIREV-SPN, Paris, 78 pp.

Simoncini R, Ring I, Sandström C, Albert C, Kasymov U, Arlettaz R (2019) Constraints and opportunities for mainstreaming biodiversity and ecosystem services in the EU's Common Agricultural Policy: Insights from the IPBES assessment for Europe and Central Asia. Land Use Policy 88: 104099. https://doi.org/10.1016/j.landusepol.2019.104099

Ssymank A (1994) Neue Anforderungen im europäischen Naturschutz: Das Schutzgebietssystem Natura 2000 und die FFH-Richtlinie der EU. Natur und Landschaft 69(9): 395–406.

Ssymank A, Hauke U, Rückriem C, Schröder E, Messer D (1998) Das europäische Schutzgebietssystem NATURA 2000 – BfN-Handbuch zur Umsetzung der Fauna-Flora-Habitat-Richtlinie (92/43/EWG) und der Vogelschutzrichtlinie (79/409/EWG). Landwirtschaftsverlag, Münster. Schriftenreihe für Landschaftspflege und Naturschutz 53: 1–560.

Von Drachenfels O (2012) Einstufung der Biotoptypen in Niedersachsen – Regenerationsfähigkeit, Wertstufen, Grundwasserabhängigkeit, Nährstoffempfindlichkeit, Gefährdung. Informationsdienst Naturschutz Niedersachsen 32(1): 1–59.

Von Hengel U, Westhus W (2011) Rote Liste der Biotoptypen Thüringens. 3. Fassung, Stand 12/2010. Naturschutzreport 26: 526–541. https://tlubn.thueringen.de/naturschutz/biotopschutz/quellenverz/

Williams RJ, Wahren CH, Stott KAJ, Camac JS, White M, Burns E, Harris S, Nash M, Morgan JW, Venn S, Papst WA, Hoffmann A (2015) An International Union for the Conservation of Nature Red List ecosystems risk assessment for alpine snow patch herbfields, South-Eastern Australia. Austral Ecology 40(4): 433–443. https://doi.org/10.1111/aec.12266

Zimmermann F, Düvel M, Herrmann A (2011) Biotoptypenkartierung Brandenburg. Liste der Biotoptypen mit Angaben zum gesetzlichen Schutz (§ 32 BbgNatSchG), zur Gefährdung und zur Regenerierbarkeit. Landesamt für Umwelt, Gesundheit und Verbraucherschutz, Potsdam.